Research into Materials for Advanced Photovoltaics

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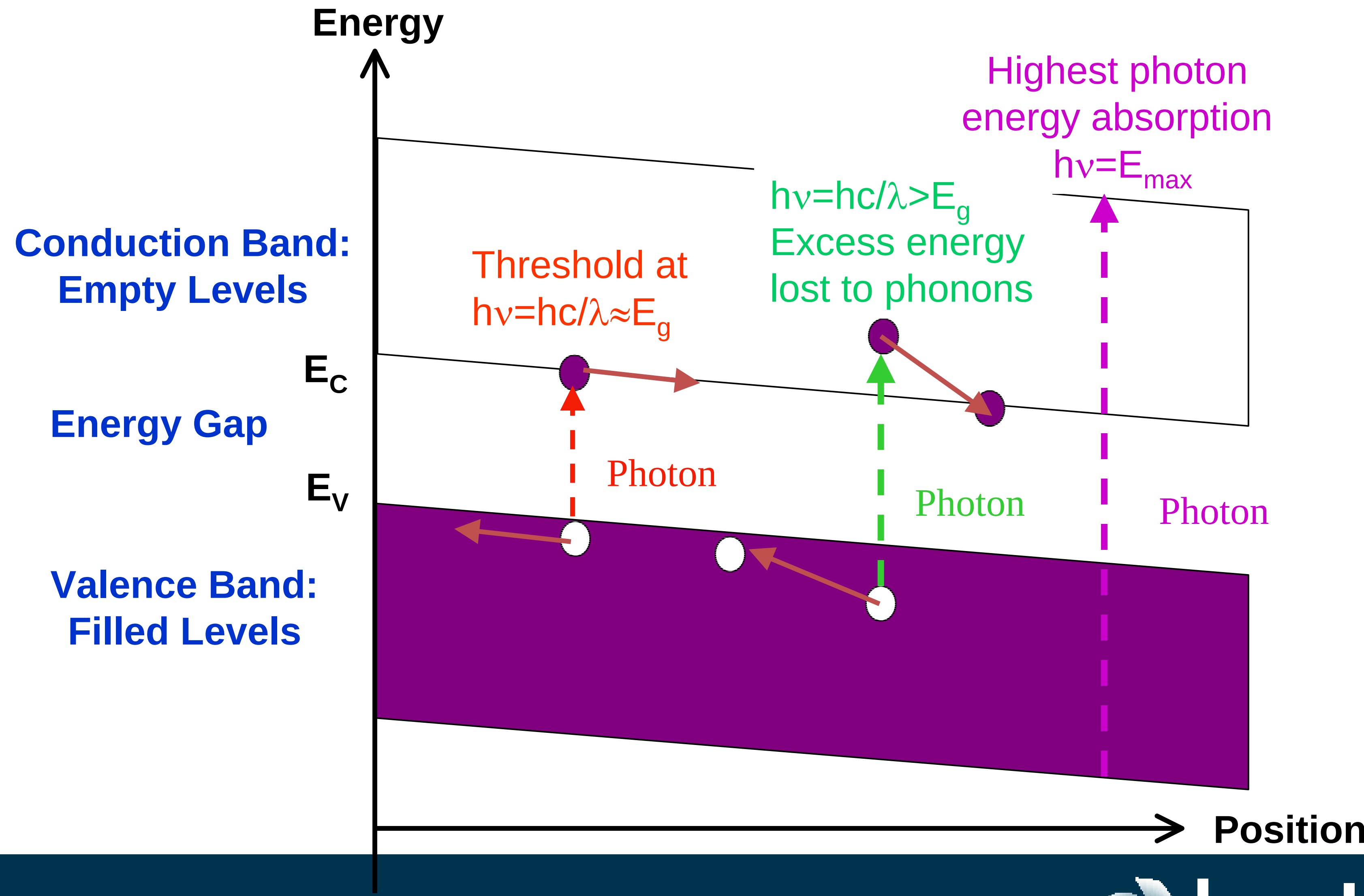
Three Generations of Photovoltaic Technology

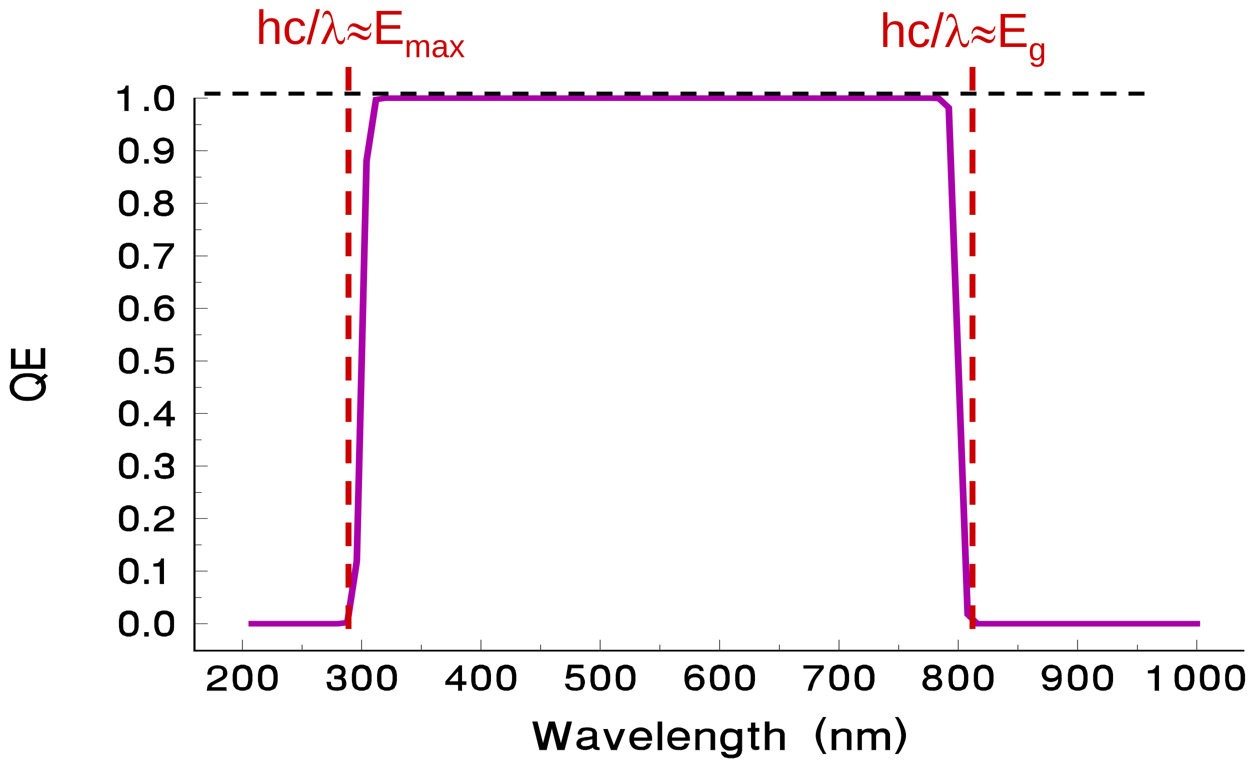
1. Single or multicrystal silicon or other semiconductor in a single junction device (typically a pn junction).
2. Thin semiconducting film on inexpensive substrates such as glass, metal foil, or plastic. Most successful materials include amorphous Si, CdTe, and the alloys of $CuInSe_2$
3. Advanced materials designs, such as nanostructured semiconducting materials, organics, etc. Such approaches still require significant basic research.

Carrier Generation at Different Wavelengths



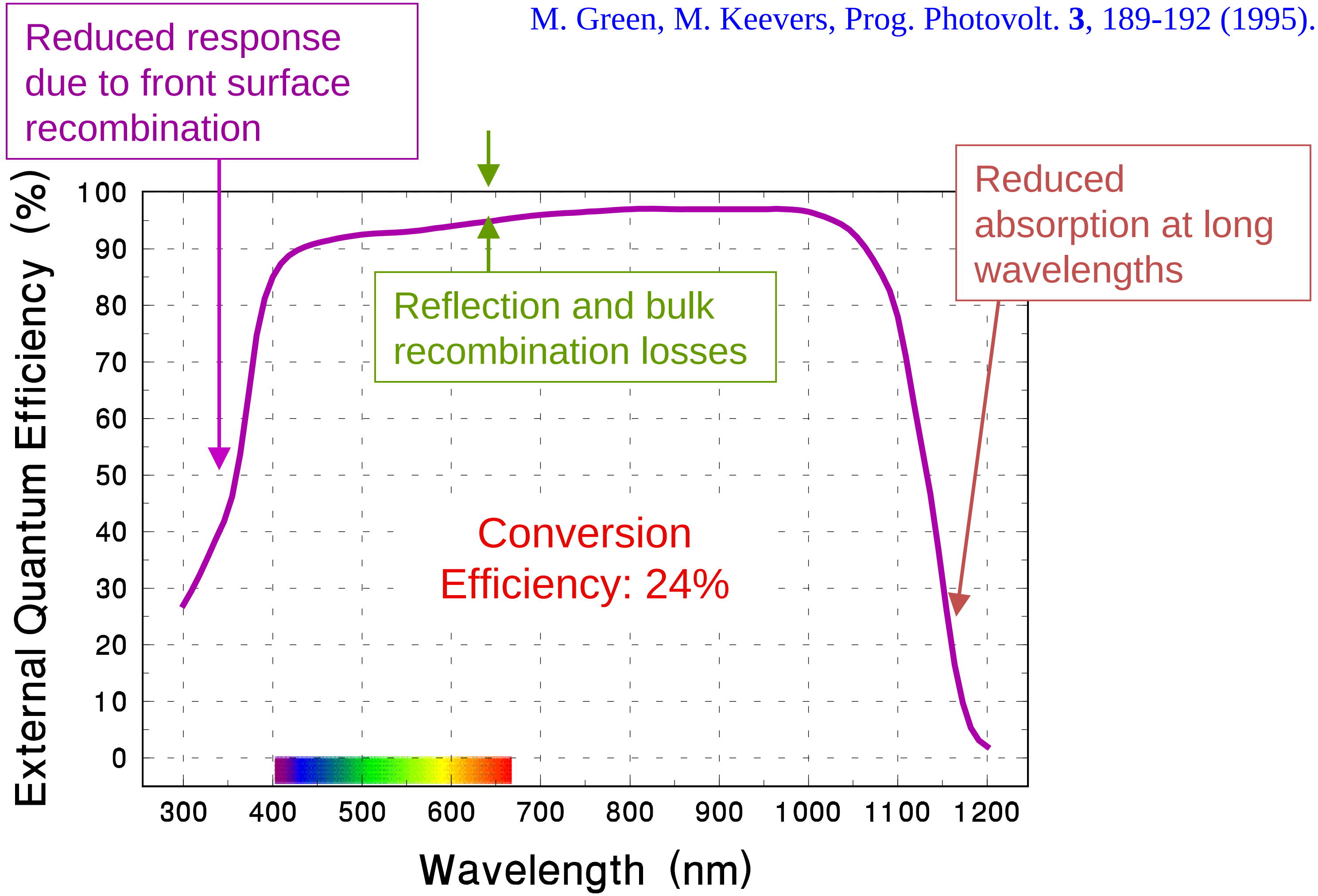
The Quantum Efficiency (QE) in Ideal Case

Each photon whose energy exceeds the semiconductor bandgap produces an electron-hole pair which gets collected up to E_{max}



Quantum Efficiency for Silicon PERL Cell

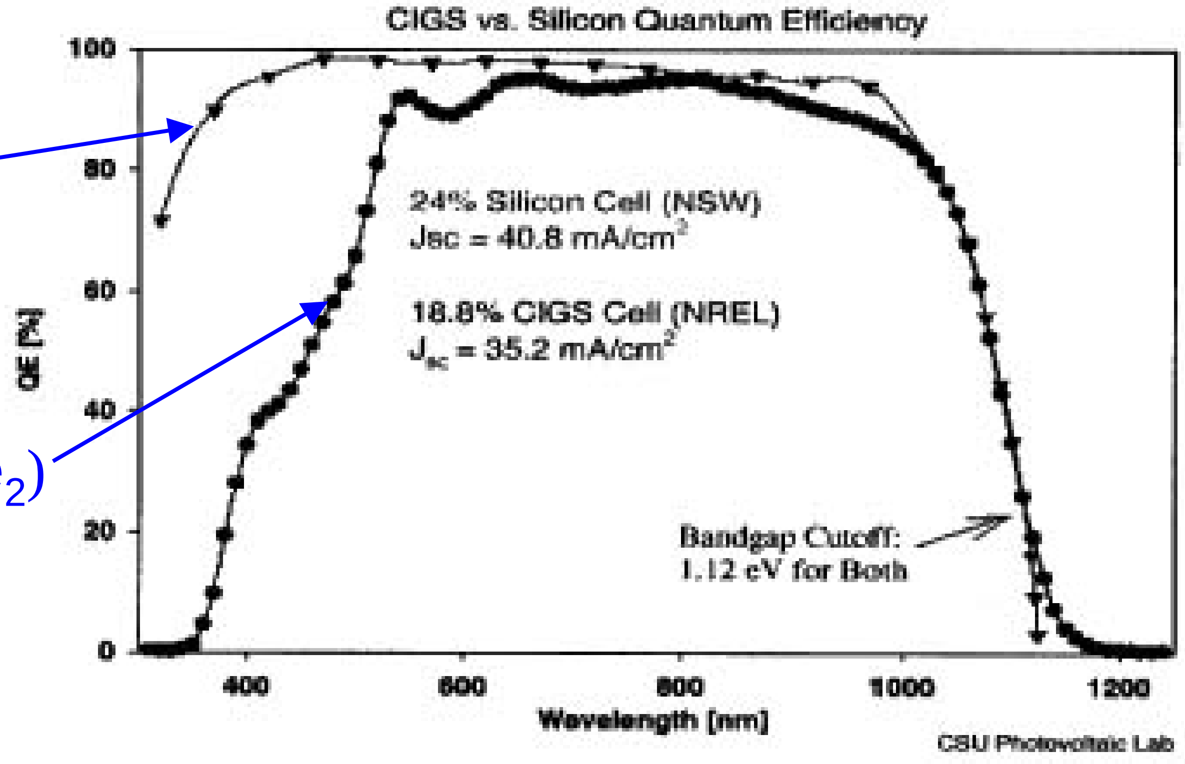
M. Green, M. Keevers, Prog. Photovolt. **3**, 189-192 (1995).



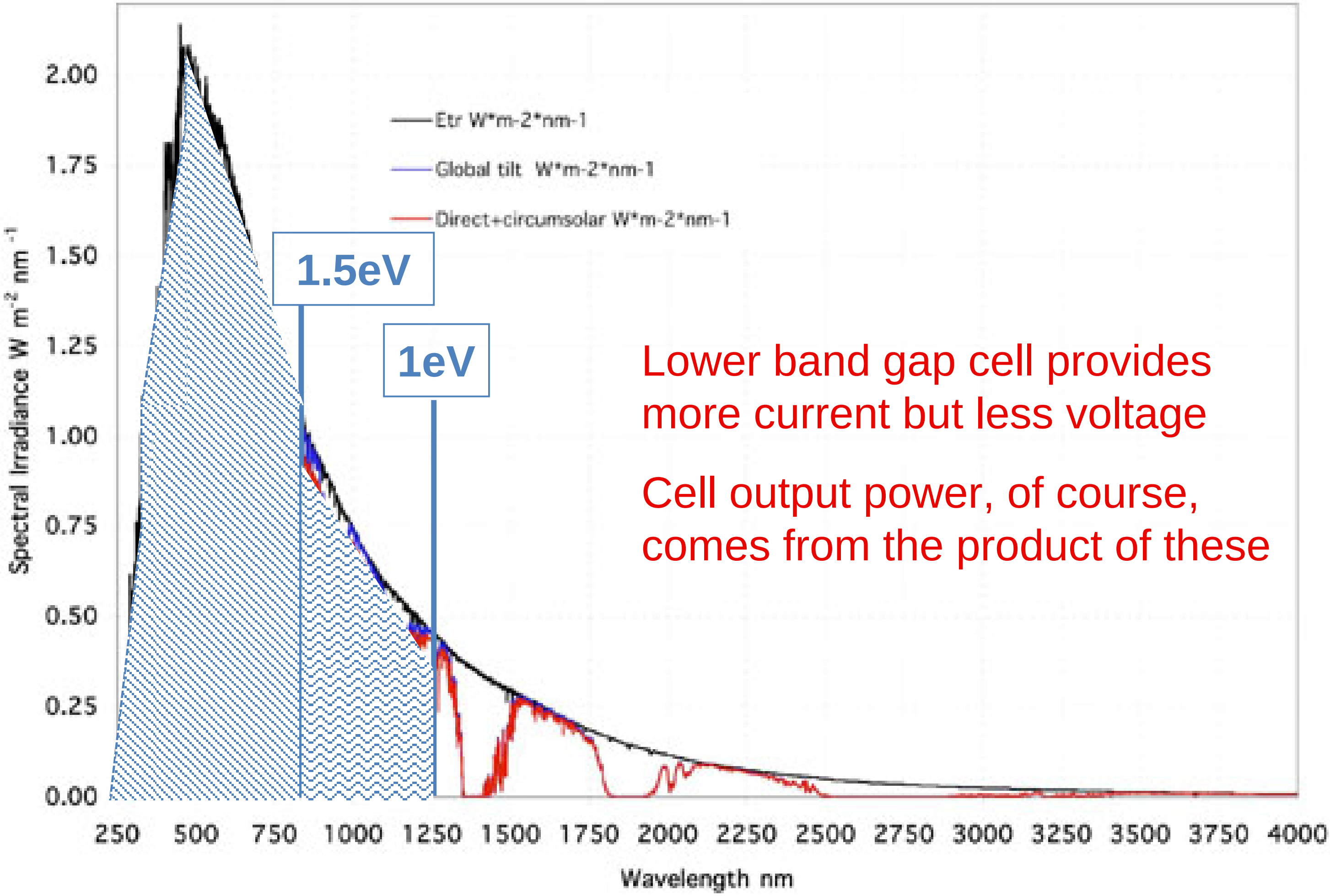
Comparing Quantum Efficiencies in the Best CIGS and Crystalline Si Cells

Crystalline Si
24.0% NSW cell

CIGS ($CuIn_{0.7}Ga_{0.3}Se_2$)
18.8% NREL cell



The Solar Spectrum Reaching Earth



Lower band gap cell provides more current but less voltage

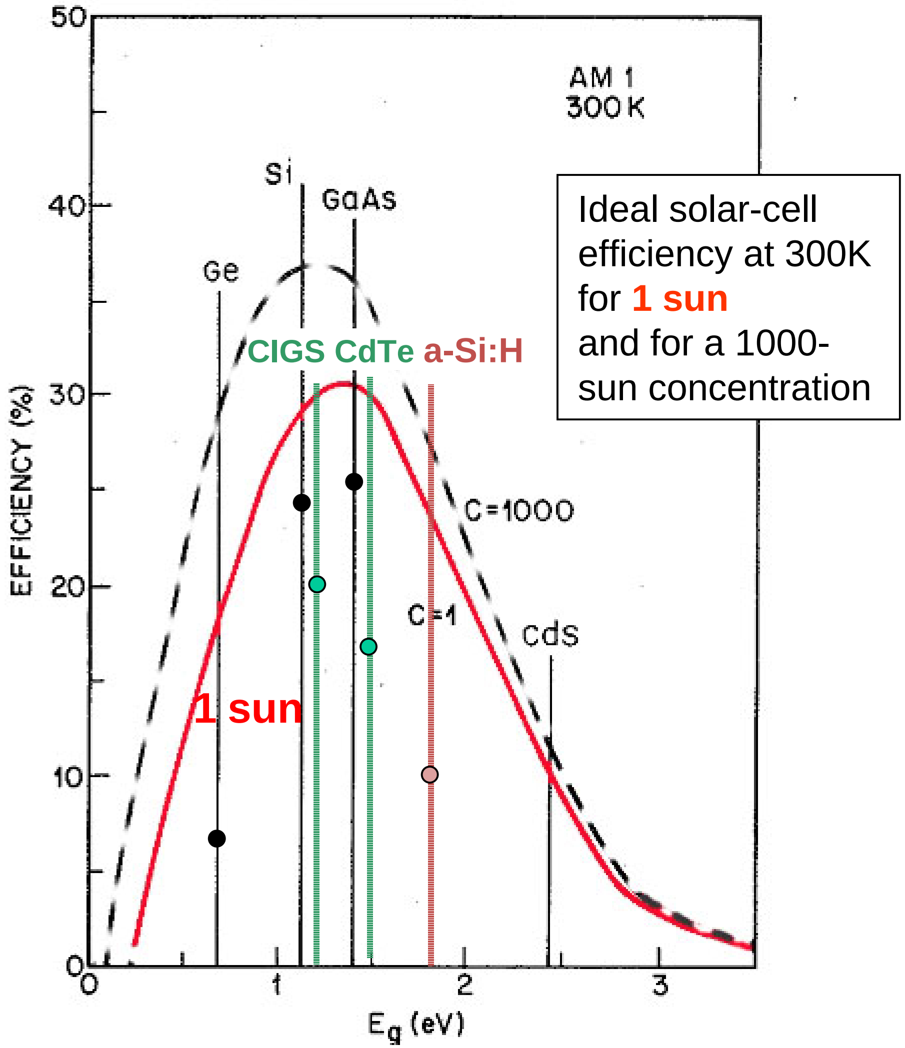
Cell output power, of course, comes from the product of these

Maximum Possible Efficiency vs. Band Gap

These predicted maximum efficiencies for single junction solar cell devices are often referred to as the **“Schockley-Queisser limit”**.*

Note that the efficiency under concentration exceeds that with 1 sun illumination

* W. Shockley and H. Queisser, J. Appl. Phys. **32**, 510-519 (1961).



Higher Efficiencies via Multi-junction Structures:

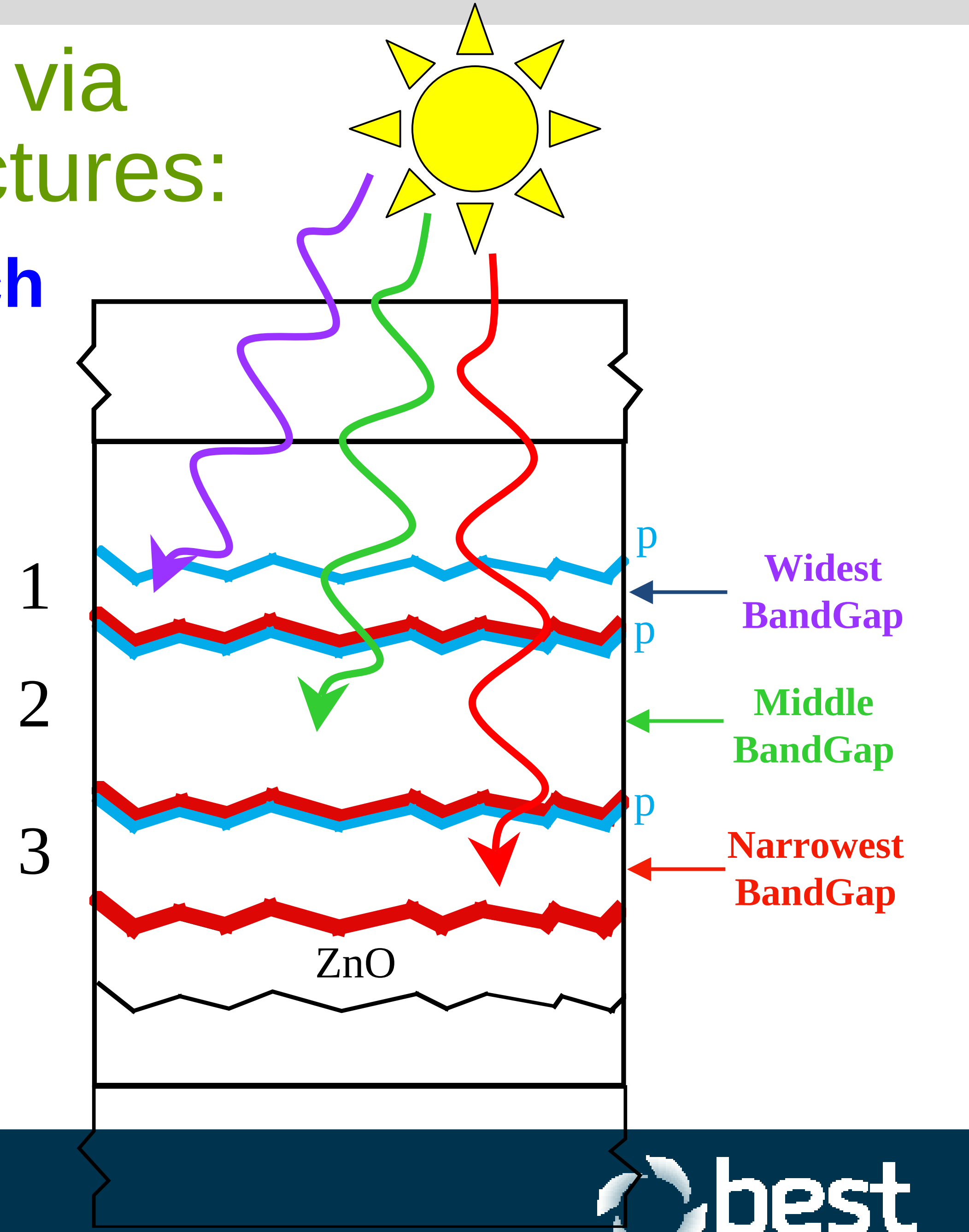
1. Traditional Approach

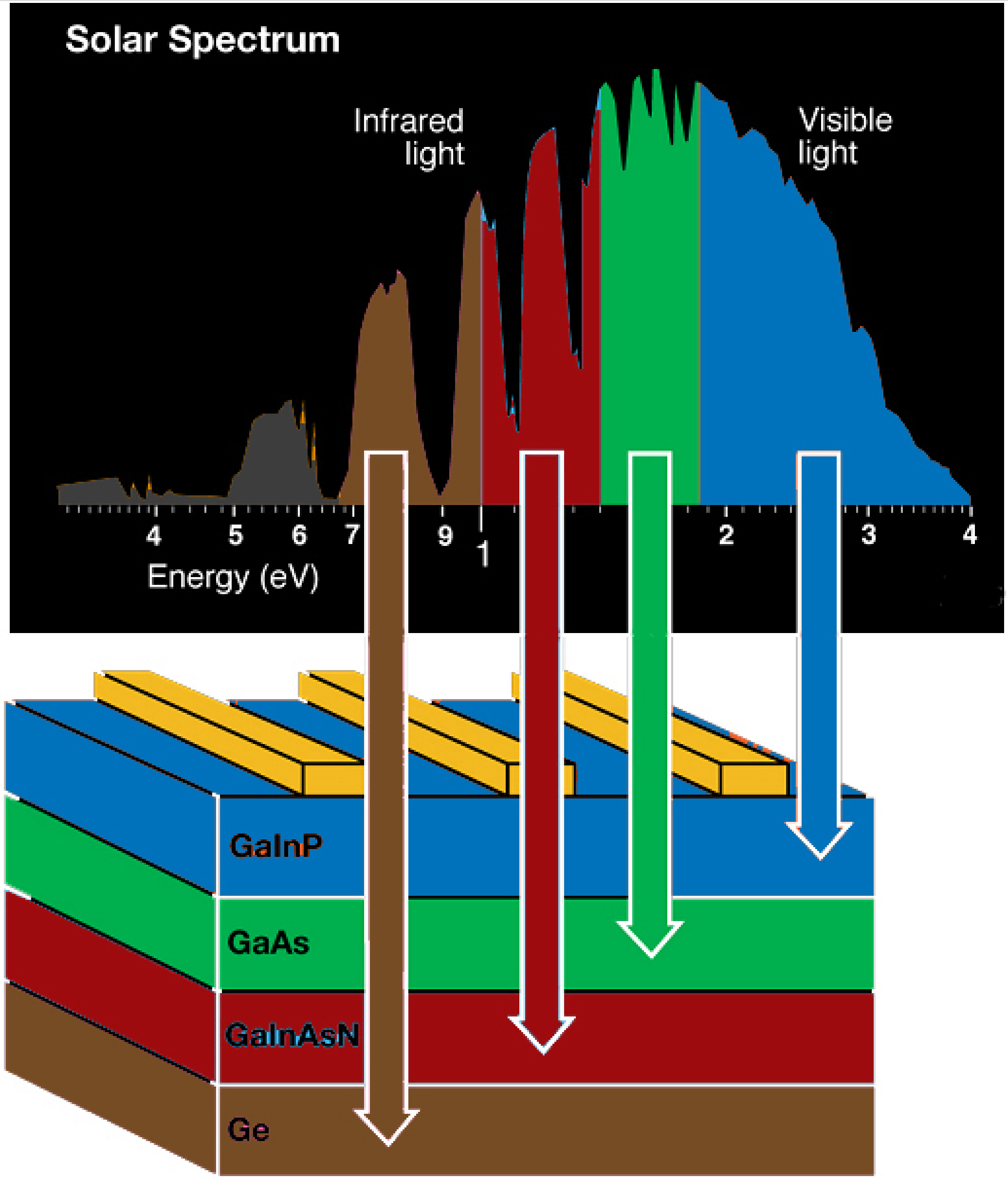
Three individual stacked solar cells using different semiconducting alloys.

Different bandgaps capture different portions of the solar spectra.

Currents in all 3 cells must match; Cell voltages will add in series

(Difficult constraints)





Theoretical Efficiencies Possible:

In space under 1 sun: **41%**

On earth with concentrator: **52%**

Current Record (August 2008):

40.8% with 326 sun concentration

Previous Work at the University of Oregon

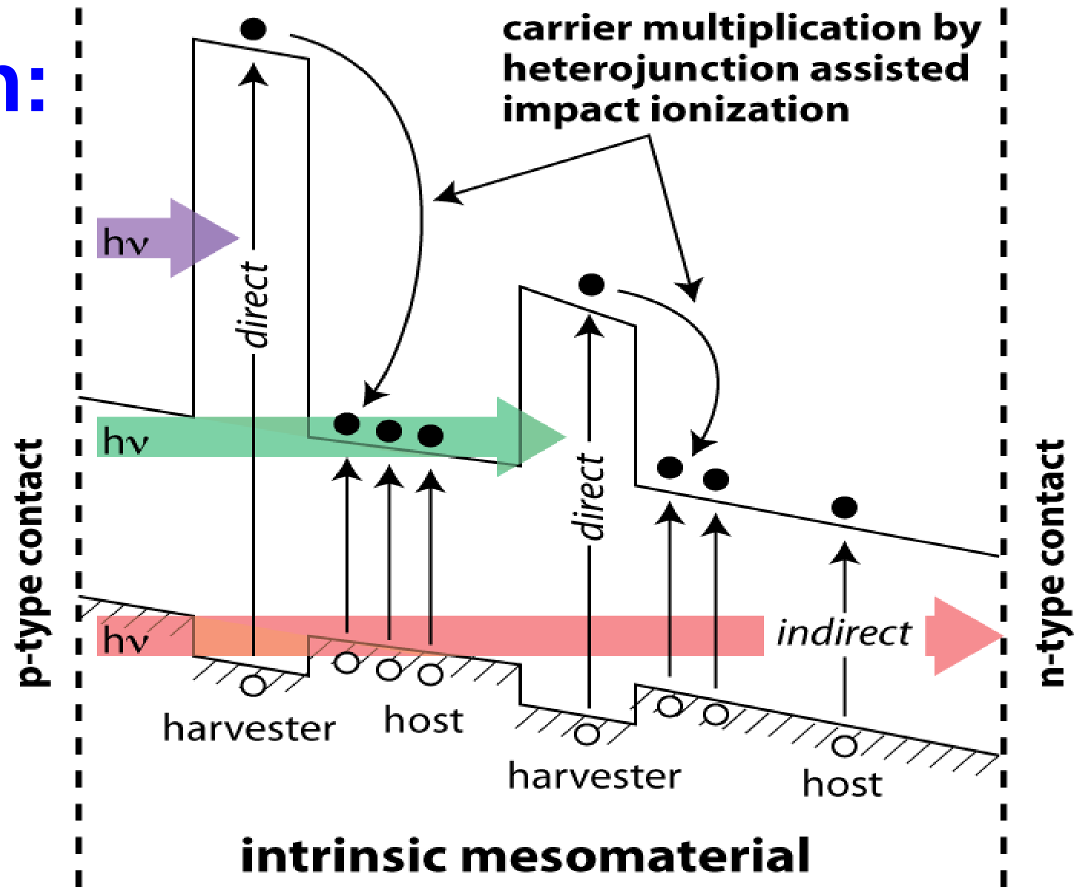
Evaluating materials for higher efficiency multijunction thin film cells:

1. Nanocrystalline silicon to be used as bottom cell for amorphous silicon based photovoltaics

2. Higher band gap chalcopyrite materials (alloys with gallium, sulfur and silver) to be used as top cell for CIGS based photovoltaics

2. A New Approach:

“Heterojunction Assisted Impact Ionization” (HAII)



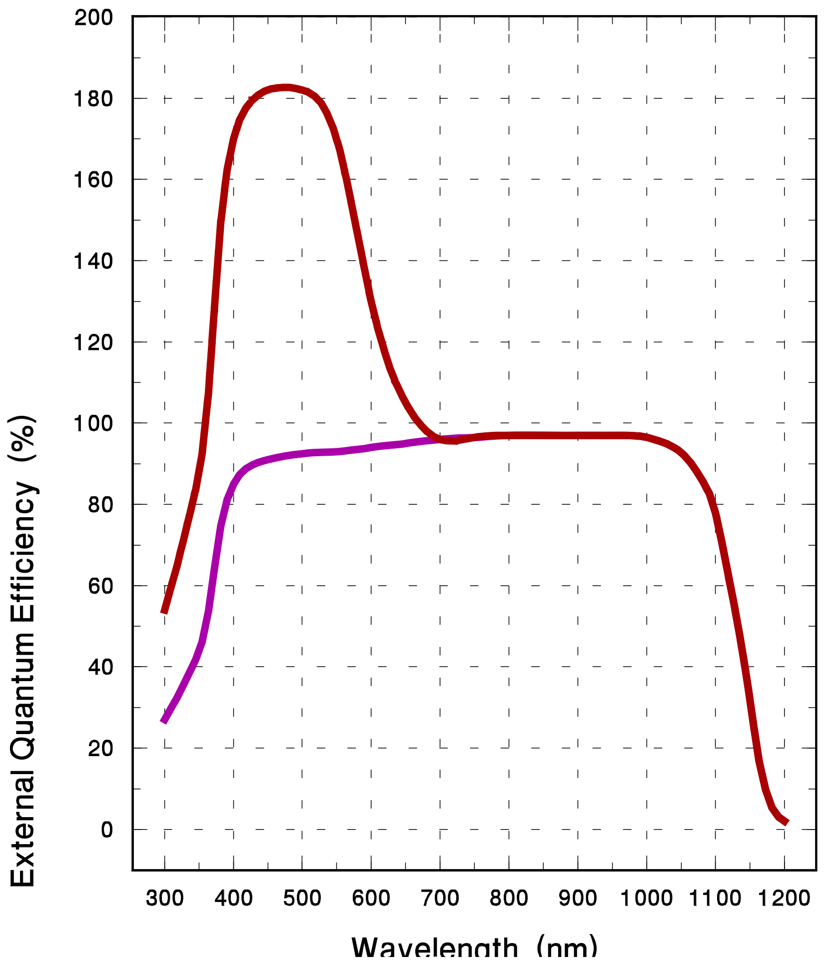
Schematic Structure of Active Region

- The active carrier generation region will integrate wide-gap light harvesting components (nanoparticles, nanorods, or 2D layers) embedded in an indirect narrow-gap charge transporting host.
- Carriers generated in the harvester move into the host, they become ‘hot’ so that additional carriers are produced by impact ionization.

Possible Quantum Efficiency for HAII Cell

In this hypothetical example the efficiency of a 24% silicon cell would be increased to over 30%

Because this approach builds upon any host device structure, it could also be applied to more modestly performing cells to obtain similar multipliers on the device efficiency (e.g. from 15% to 19%)

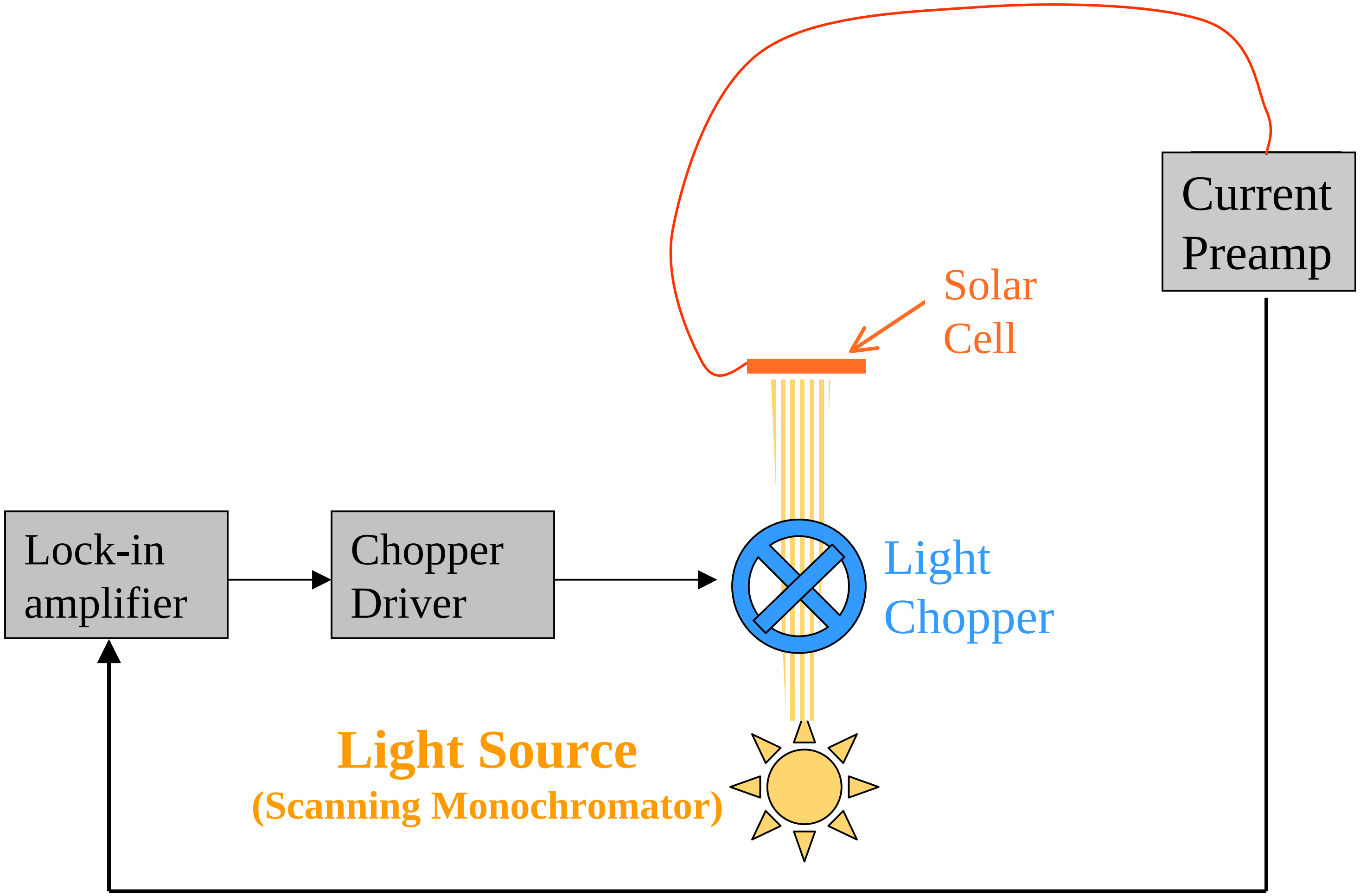


Key Tasks in Realizing Our Approach

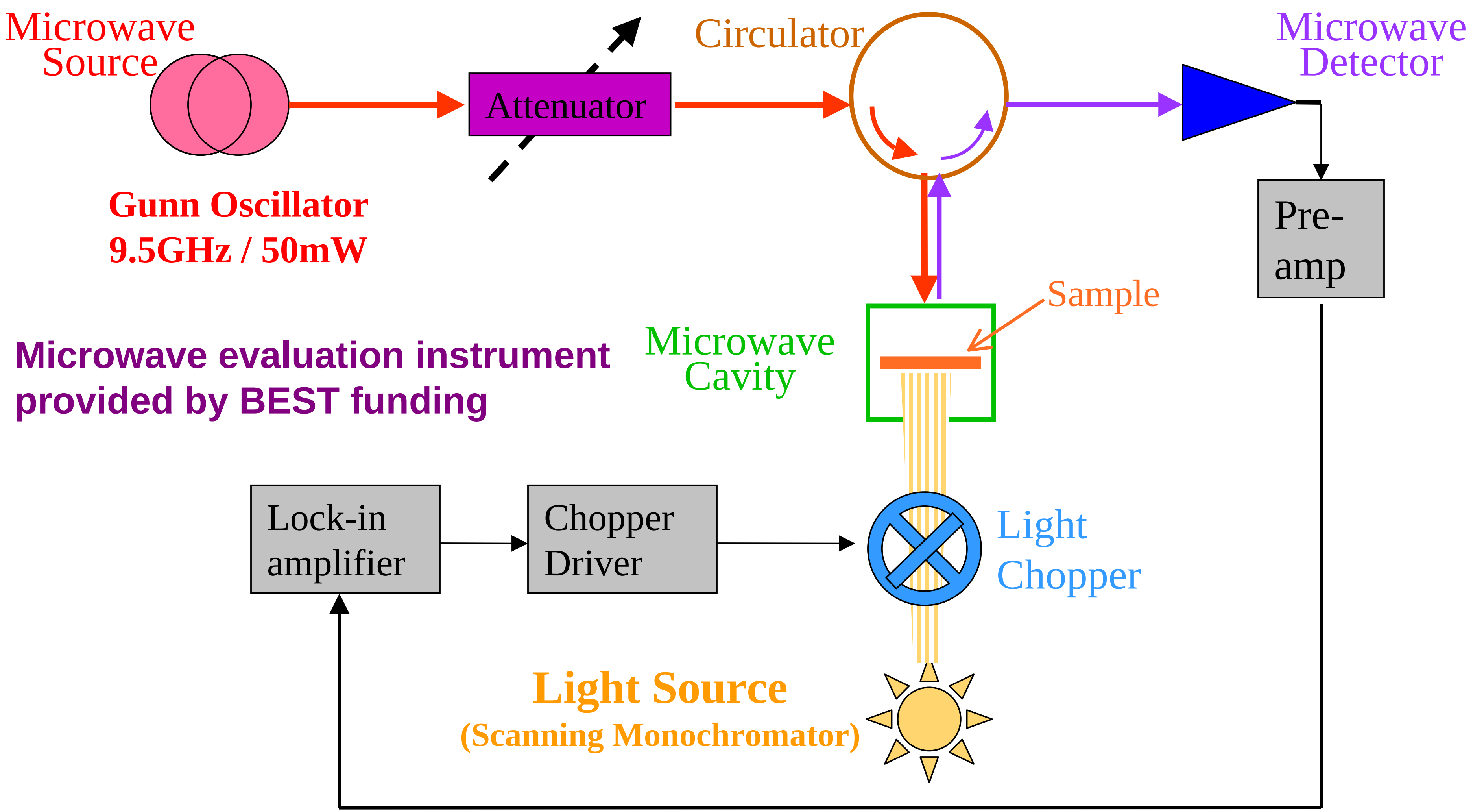
1. Synthesis of such structured composite materials
2. **Rapid Screening of many sample series to identify most promising candidates**
3. Detailed study of carrier transfer dynamics and recombination processes to optimize effect
4. Fabrication of prototype devices for testing

Quantum Efficiency Measurement of Solar Cell

(to determine the number of carriers generated per photon)



Contactless Microwave Photoconductivity Measurement



Microwave evaluation instrument provided by BEST funding

Summary

- Three “Generations” of photovoltaic technologies – University research must generally concentrate on “Third Generation” approaches
- Recent research at the University of Oregon has focused on thin-film photovoltaics and characterizing promising materials for multijunction solar cells
- A new approach is being explored: “heterojunction assisted impact ionization” (HAII). This can increase the quantum efficiency above 100% at short wavelengths, thus improving cell efficiencies
- We are implementing a contactless microwave photoconductivity apparatus, purchased from BEST funds, to enable rapid screening of candidate HAII composite materials